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CBCT in Orthodontics: A Boon for the Millennial Generation

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Abstract---Most orthodontic patients, unlike those having implants or endodontic treatment, are children who are particularly vulnerable to ionising radiation. In orthodontics, cone-beam computed tomography (CBCT) has both hazards and benefits. Ionizing radiation, the existence of artefacts, higher costs, limited accessibility, and the need for additional training are the main hazards and limits. This imaging modality, however, has several recognised indications in orthodontics, including the assessment of impacted and ectopic teeth, the assessment of pharyngeal airway, the assessment of mini-implant sites, the evaluation of craniofacial abnormalities, the evaluation of sinus anatomy or pathology, the evaluation of root resorption, the evaluation of the cortical bone plate, and the planning and evaluation

of orthognathic surgery. For certain patients, CBCT should be considered for clinical orthodontics. The use of CBCT requires careful consideration and strong clinical judgement. The important themes and topics in the literature about application of CBCT in orthodontics are summarised in this review.

Keywords--CBCT, computed tomography, cone beam, evidence-based diagnosis, orthodontics, three-dimensional imaging.

Introduction

CBCT was first used in dentistry in Europe in 1998 (Mozzo et al., 1998). CBCT (cone-beam computed tomography) is a radiographic technology that was first presented to the dentistry industry in the United States in 2001. An early appraisal of the technology's potential future impact on dentistry, specifically orthodontics, was first discussed and reported in the proceedings of a symposium on "Craniofacial Imaging in the Twenty-First Century" held in Pacific Grove, CA in 2002 (Kapila & Farman, 2003). Few other diagnostic imaging modalities had this same impact on dental clinic as CBCT has been around since the invention of the X-ray more than a century ago. The advancement in CBCT maxillofacial applications has been impressive since its introduction. Since then, CBCT technology has advanced quickly, owing in large part to the needs of each specialty for accurate, repeatable, and safe three-dimensional (3D) pictures. In orthodontics, 3D imaging can aid in the deciphering of the complexities of dental and skeletal malocclusions, as well as improving diagnosis and treatment planning in specific cases.

A cone-shaped source of ionising radiation and a two-dimensional detector are used in CBCT technology. For diagnostic and treatment planning, it delivers multidimensional and dimensionally accurate images. These images contain isotropic voxels (volume elements) with equal dimensions in all three orthogonal planes, allowing the practitioner to create correct multi-planar views in any direction⁵. Routine radiographs are not recommended for any patient in any dental profession, including orthodontics, according to both European and American radiography guidelines, because the risk of unnecessary ionising radiation exposure may outweigh the benefits. In reality, three systematic reviews agree that two-dimensional (2D) and three-dimensional (3D) radiographs are not required for orthodontic diagnosis or treatment planning (Durão et al., 2013; Pittayapat et al., 2014).

Practitioners who want to enhance diagnosis and treatment for their patients have been paying close attention to CBCT. There have been documented CBCT indications in orthodontics. However, in each situation, the hazards and limitations of CBCT must be investigated and weighed against the benefits of CBCT. Indeed, according to the findings of the systematic reviews, these 2D radiographs should only be done when they are likely to provide extra information that can aid in diagnosis or treatment planning, as well as for assessing progress or problems during therapy. A substantial number of original CBCT research have focused on craniofacial and airway morphometric analyses in health and disease,

CBCT usage in treatment outcome analysis, and evidence-based indications, uses, and efficacy of CBCT in diagnostic and treatment planning. This article highlights the use of CBCT in a variety of orthodontic activities, ranging from basic to advanced. It also looks ahead to see how CBCT might become a standard part of high-tech orthodontic treatment in the future.

Application of CBCT Impacted teeth

Maxillary canines are the second most usually impacted teeth after third molars, and are probably the most prevalent indications for CBCT imaging in orthodontics. Indeed, of the numerous types of clinical scenarios presented to orthodontists, impacted teeth are the ones in which CBCT has been found to improve diagnosis and contribute to treatment planning modifications in a large number of patients (Bedoya & Park, 2009; Manne et al., 2012). The most well-known application of CBCT imaging in orthodontics is the examination of impacted canines. CBCT imaging is useful for establishing not only the labial/lingual connection, but also the angulation of the impacted canine. CBCT improves the ability to accurately localise impacted canines, assess their proximity to other teeth and structures, determine follicle size and pathology, estimate space conditions, assess resorption of adjacent teeth, plan surgical access and bond placement, and define the optimal direction for extrusion of these teeth into the oral cavity (Walker et al., 2005; Lai et al., 2013; Oberoi & Knuettel, 2012; Alqerban et al., 2011; Alqerban et al., 2009; Kapila & Nervina, 2014). These 3D images are useful for determining the proximity of adjacent incisor and premolar roots, which can help determine how simple uncovering and bonding will be. It also aids in determining the force vector. A periapical image of a maxillary canine that should be used to advance the tooth into the arch with the least amount of adjacent root resorption possible (Ericson & Kurol, 1988).

Root angulation, morphology and resorption

Root resorption is a common and unfavourable side effect of orthodontic therapy that can shorten the longevity of teeth. Periapical radiographs have typically been used to assess root length, shape, and resorption. For assessing tooth and root length, CBCT has been demonstrated to be at least as good as periapical radiography. Furthermore, because CBCT can produce precise images of minor root abnormalities, it provides more detailed insights into root resorption and has higher sensitivity and specificity in detecting these lesions than panoramic or other 2D radiography. Panoramic radiographs also underestimate the presence of external apical root resorption when compared to CBCT (EARR). Finally, whereas 2D radiographs only show the apex as well as the mesial and distal root surfaces, CBCT imaging also shows the buccal and lingual root surfaces (Lund et al., 2010; Sherrard et al., 2010; Alqerban et al., 2009; Durack et al., 2011; Ponder, 2011; Ponder et al., 2013; Ren et al., 2013). This has led to the revelation that root loss occurs not only at the root apex, but also on surfaces adjacent to the direction of tooth movement as a slanting root loss. This finding emphasises the value of CBCT's 3D rendering capability in accurately diagnosing EARR and other previously unknown forms of root resorption. As a result, high-resolution CBCT may bring about a new diagnostic criteria of root resorption affecting root surfaces

visible by 3D but not by 2D radiographs, in addition to the previously accepted diagnosis of EARR seen on 2D radiographs. Although root parallelism is a key goal of orthodontic treatment, determining it accurately can help assess the quality of treatment outcomes and, perhaps, post-treatment stability. Panoramic radiographs are commonly used to detect root parallelism and relationships, which often reveal abnormalities in root angulation, particularly in the maxillary and mandibular anterior teeth (Garcia-Figueroa et al., 2008; Mckee et al., 2002; Owens & Johal, 2008).

Fractured roots

It can be challenging to see root fractures radiographically if they are in an oblique direction. The tooth of interest can be visualised in all three planes of space using CBCT, making it easier to evaluate the location of the root fracture and the degree of displacement (Melo et al., 2010).

Supernumerary teeth

The scientific evidence that CBCT is superior to 2D radiography for impacted tooth diagnosis and treatment planning could be used to supernumerary teeth. Additional teeth can form anywhere in the dentition, although they are most usually found in the anterior maxilla, and they can be difficult to differentiate from normal teeth. In these circumstances, there are two imaging objectives. The basic stage is to identify all extra teeth, many of which are still erupting or may be impacted. The next purpose is to examine the morphology of the extra teeth in greater depth. The use of information acquired from CBCT images of unerupted supernumerary teeth could help with judgments on which teeth to keep, determining their retrievability, and mapping the best surgical access to the teeth (Toureno et al., 2013).

Location of anatomic structures

The mental foramen, inferior alveolar nerve, maxillary sinus, and surrounding roots can all be seen clearly with CBCT. CBCT scans also allow practitioners to precisely estimate distance, area, and volume, which aids treatment planning for sinus lifts, ridge augmentations, extractions, and implant implantation.

Maxillary transverse dimension and maxillary expansion

Malocclusions characterized by posterior crossbites and often accompanied by crowding and/or increased overjet are caused by maxillary transverse deficit. In growing individuals, RME is used to correct these occlusal and maxillary arch defects in order to extend the maxillary transverse dimension, largely by widening the mid-palatal suture. In these circumstances, the purpose of RME therapy is to restore the normal posterior transverse occlusion and lengthen the arch to reduce crowding through skeletal expansion and/or dental tipping. CBCT has allowed for a more detailed dissection of bone and tooth responses to maxillary expansion than 2D radiography or research models could provide. The efficacy of CBCT in the diagnosis and treatment planning of transverse discrepancies has yet to be determined in RME studies. CBCT was used to answer two main concerns about

RME treatment: how expansion pressures influence distinct regions of the maxilla and how age affects the relative degree of skeletal expansion versus dental tipping. Few studies show that tooth-borne RME therapy causes the separation of many circum-maxillary sutures, resulting in an increase in not only the transverse but also the sagittal and vertical dimensions in growing youngsters (Habeeb et al., 2013; Woller et al., 2014).

Cleft lip and palate

In 2D images, estimating the size (dimensions) of the osseous abnormalities and their spatial relationship to other key anatomic structures is difficult. The exact anatomic relationships and bone thickness around the existing teeth in proximity to the cleft or clefts can be determined using CBCT. This data is crucial for the planned grafting treatments as well as possible tooth movement in the existing dentition. Pre-alveolar graft radiographs offer the orthodontist and surgeon with information on how much expansion and graft material will be required to allow the canine to erupt at a later stage of treatment. Although 2D radiographs have been employed in the past for these objectives, the ability to identify the precise volume of the post-expansion defect and hence ideally plan the surgery and amount of donor tissue required may provide relative advantages of using CBCT over 2D radiographs. In patients with CL/P, CBCT pictures are useful for measuring the volume of the alveolar defect and, as a result, the amount of bone needed for grafting, as well as determining the success of bone filling after surgery (Hamada et al., 2005; Wortche et al., 2006; Oberoi et al., 2009; Shirota et al., 2010; Oberoi et al., 2014).

Temporomandibular joint morphology and pathology contributing to malocclusion

Traditional tomography has been widely utilised for TMJ evaluation; however, the sensitivity of the technology and the length of the examinations have made it a less appealing diagnostic tool for dentists. In detecting condylar erosions, CBCT pictures of the TMJ have been demonstrated to be more reliable and accurate than tomographic or panoramic views. Temporomandibular dysfunction can make orthodontic treatment more difficult, thus it's important to check TMJ anatomy before, during, and after orthodontic treatment. Follow-up CBCT scans taken over a long period of time can help the orthodontist assess the progression of any suspected degenerative changes (Honey et al., 2007; Tsiklakis et al., 2004).

Maximizing the visualisation of these changes could help in determining the magnitude of degenerative changes and distinguishing the finer details of joint pathology, which is important for accurate diagnosis and referral of patients to the appropriate specialists before beginning orthodontic treatment. CBCT images of the TMJ provide clinicians with more accurate anatomic detail than standard 2D panoramic radiographs, as expected. CBCT enables for reliable detection and evaluation of pathological changes by allowing for observation of modest to overt osseous hard tissue changes and congruency of articulating surfaces arising from disease and adaptive processes. Finally, shape correspondence comparisons of asymptomatic control and osteoarthritic TMJs revealed significant differences in the morphologies of healthy and degenerative condyles, as well as strong

correlations between pain severity and local anatomic changes in the condyle (Honda & Bjørnland, 2006; Honey et al., 2007; Alkhader et al., 2010; Cevidanes et al., 2010).

Pathologies of Jaws

On panoramic radiographs, radiopaque lesions near the apexes of teeth, such as enostosis, condensing osteitis, thick bone island, and focal apical osteopetrosis, are difficult to see. They don't appear to be caused by anything, yet they can inhibit tooth mobility. CBCT images make it simple to see such lesions (Yonetsu et al., 1997; Bsoul, 2004).

Superimposition

The development of CBCT has allowed clinicians to make three-dimensional superimpositions, removing some of the inaccuracies that can arise with standard lateral cephalometric superimposition. These three-dimensional superimpositions aid in the evaluation of therapy outcomes.

Airway morphology, vertical malocclusion and obstructive sleep apnoea

In children who develop a mouth breathing habit, a constricted pharyngeal airway is thought to be a possible factor to vertical malocclusion. Furthermore, orthodontists are becoming increasingly interested in airway morphology, its association to OSA, and the impact of orthodontic treatment on OSA. Clinically, a constrictive airway is frequently diagnosed, especially in children with larger adenoids and tonsils. Airway constriction in the sagittal plane can also be diagnosed with conventional 2D lateral cephalographs, which have been employed in some of the most recent investigations on airway changes after orthodontic treatment. However, it has been suggested that volume or cross-sectional area may be a better indicator of airway constrictions, which would necessitate the use of CBCT rather than traditional imaging (Nielsen, 1991; Pamporakis et al., 2014; Bahler et al., 2012; Alsufyani et al., 2013; Han et al., 2014; Vinoth et al., 2013; Celikoglu et al., 2014; Peck et al., 2007).

Orthodontic implants placement

The ability to understand root orientation can considerably improve the chances of successful orthodontic implant insertion and placement. Panoramic radiographs are less accurate and reliable than CBCT images for viewing inter-radicular relationships. In anatomically difficult sites, CBCT data can be used to create placement guides for placing mini-implants between the roots of adjacent teeth. Before the mini-implants are inserted, the amount and quality of the bone at the intended placement areas can be assessed (Peck et al., 2007; Kim et al., 2007; Macchi et al., 2006; Wong, 2002).

Conclusion

The ability of CBCT to improve diagnostic and treatment planning may be beneficial to some orthodontic patients. The proper use of CBCT, which involves

obtaining CBCT only when absolutely necessary, has the potential to limit ionising radiation exposure in orthodontic patients. In most circumstances, the dangers of CBCT scans in orthodontics are balanced by the benefits that CBCT scans give in cases where traditional radiographs are insufficient for diagnosis and treatment planning. Future advancements in this sector promise to improve orthodontic diagnosis and treatment even more. The long-awaited integration of 3D into our radiography records is rapidly approaching. The future of orthodontics is CBCT, and the applications in orthodontics appear to be nearly unlimited.

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